EVALUATING THE ACCURACY OF DISTANCE AND ANGLE ESTIMATIONS IN LINE TRANSECT SAMPLING: PRELIMINARY REPORT ON ACTIVIES OF FWS AGREEMENT #: 1448-10110-97-J132 AND DCN 10110-7-4000

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INTRODUCTION

At-sea population monitoring for the Marbled Murrelet relies on accurate methods to estimate population densities. Becker et al. (1997) suggested that the line transect method should replace strip transects as the standard method for surveying murrelets at sea. Line transect surveys should satisfy three assumptions for precise and accurate density modeling: (1) all birds are detected on the transect line, (2) birds are detected at their initial locations, and (3) measurement of distance from the bird to the transect line is exact (Buckland et al. 1993). This report presents preliminary results of experiments during 1997 and 1998 testing the training and accuracy of distance and angle estimates that are necessary to satisfy assumption 3. Results will be important for understanding and improving the accuracy of at-sea line transect surveys to detect Marbled Murrelet population trends (U.S. Fish and Wildlife Service 1997).

Estimates of a murrelet's distance from the transect line should be made as soon as the bird is observed in front of the boat, because it is necessary to detect birds at their initial locations (assumption 2). This may be accomplished by either (1) estimating the location of the transect line ahead of the boat and estimating the distance between the transect line and the murrelets, or (2) by estimating the bird's angle of declination from the transect line, and estimating the distance from the boat to the bird. The formula $D = x \sin \Theta$, where x is the distance from the boat to the bird and Θ is the angle between the transect line and the bird, is then used to calculate the distance (D) of the bird from the transect line. Each method may have estimation errors, however, it may be more practical to test errors associated with method 2 since all estimations are made from the observer (the boat) to the bird, rather than between two removed points in space. This makes the second method more amenable to error assessment.

This study presents preliminary results of field tests of the accuracy of distance and angle estimations using method 2, and suggests methods for improving estimates in the future. This work is part of an attempt to validate a standardized and repeatable marine survey methodology that will allow accurate estimates of murrelet population size and density.

METHODS

Evaluation of the accuracy of distance estimates involved determining the differences between distance or angle estimated by observers from the boat to a floating object, and the object's actual distance or angle. First, observers were trained in distance and angle estimation, and later testing was done repeatedly. Two observers and one trainer/tester participated in this study.

Distance Estimation Training and Testing

The two observers were trained to estimate the exact distance to an object, daily for one week and thereafter were refreshed before each boat survey. A Marbled Murrelet sized float (20 cm) was attached to the end of 120 m rolling measuring tape. The two observers were trained simultaneously by the trainer. The trainer let out the tape to random, known distances, while the boat moved slowly forward (2 km/hr) to keep the tape in a straight line. Observers independently made an estimate of distance without knowing the other observer's estimate. The examiner then informed the observers of the actual distance to the float. This procedure was repeated ten times per day for a week and then 5-7 times before a testing sequence. The practice session immediately prior to each testing sequence simulated the practice training that occurs daily before an actual survey.

Procedures for testing the accuracy of distance estimates were similar to training sessions but were more structured. After the float was let out to a random distance between 1 and 120 m from the boat, the examiner and each observer recorded the distances into a microcassette recorder out of hearing range each other. During tests, observers were not corrected or given any information and the examiner was not aware of their estimates. Tests consisted of estimating 10 - 15 distances. A total of 727 paired samples of actual and estimated distances were performed. Some observation groups may have had less practice, but nonetheless, engaged in practice before each test. Experiments were conducted from a Zodiac, Boston Whaler's (17 and 21 ft) or a 30 foot vessel. Tests were completed in 1997 and 1998 by cooperative groups at the Washington Department of Natural Resources (Chris Thompson), Crescent Coastal Research (Craig Strong), and USFWS Arcata office (Dennis Therry), and UC Berkeley (Steve Beissinger and Ben Becker).

Angle Estimation Training and Testing

Training in estimating angles was also undertaken before errors in angle estimation were examined. We used an Apelco electronic digital compass with a published accuracy of ± 2 degrees to evaluate the accuracy of angles estimated from angle boards. The electronic compass is equipped pistol sights, and therefore is very stable and accurate. The electronic compass can measure the true angle to an object by taking the difference between the bearing of the transect line and the bearing to the object.

Observers practiced with angle boards constructed by laminating a paper protractor outline with 5° increments stapled to a 2 x 16 x 26 cm board. Small (2 cm) nails were placed at each 10° increment around the board to aid in obtaining the degree reading. Readings were made while holding the angle board flat and facing straight (the zero degree mark) towards a reference landmark used as a surrogate for the transect line. A landmark was used in lieu of the transect line since it is a concrete object with a known location. The observer then used the nail heads to sight a murrelet or other bird on the water and reads the declination from zero (the landmark/transect line). Observers were trained by estimating the angle between the landmark and the bird with the angle board and then immediately taking the same measurement with the digital compass. Results were immediately shared and corrections are made. This was repeated ten times per practice session.

Testing for accuracy of angle estimates was similar to training efforts. However, observers reported the angle estimated from the angle board and electronic compass into a micro-cassette tape recorder. Observers were always unaware of the actual measurements and of the angle estimates of other observers. Each test consisted of estimating 10 - 15 angles. A total of 209 tests were completed in 1997 and 1998.

Statistical Analyses

Data for both angle and distance were analyzed by taking the difference between the actual value and the estimate for each observer. Analyses of both actual and absolute error values were conducted. The distribution of error values was compared to the expected distribution from a normal distribution. Analyses also considered effects of magnitude of actual angle or distance on error. Errors were tested for effects from observer (11 distance and 4 angle observers), distance class (0 - 40 m, 40 - 80 m, and 80 - 120 m) or angle class (0 - 30°, 30 - 60°, and 60 - 90°) using 2-way ANOVA.

RESULTS

Distance Tests

The error in distance estimates (estimated - actual) averaged -2.2 ± 3.2 m for all 11 observers for all distance classes pooled (N = 727). Individual observer errors ranged from -7.1 ± 9.4 m to 4.1 ± 5.3 m (Figure 1). Error in distance estimates and histogram inspection indicated that the distributions were not highly skewed. Therefore, parametric statistics were used to search for differences among observer and distance categories. A two-way ANOVA showed that there was an effect of observer on magnitude of error in distance ($F_{10, 694} = 6.391$, $P < 0.001$), but no effect of distance class on error ($F_{2, 694} = 1.535$, $P = 0.216$) (Table 1). The interaction of observer and distance class had a highly significant effect on distance error ($F_{20, 694} = 2.062$, $P < 0.004$). The trends of least squares means by observers and distance classes showed no apparent trend in error with distance class among all observers (Fig. 2).

Angle Tests

Errors in angle estimates (estimated - actual) were distributed normally and averaged 2.1 ± 10.4 degrees (N = 209) (Fig. 3). Two-way ANOVA showed no effect of angle or observer on magnitude of error in angle estimation ($F_{3, 197} = 0.473$, $P < 0.624$ and $F_{2, 197} = 0.1.623$, $P < 0.185$, respectively) (Table 2). There was an interaction effect between angle and observer ($F_{6, 320} = 3.505$, $P < 0.003$), however this was due to only a few cases (6 of 66 comparisons) when examined using Tukey HSD. Least squares means of angle errors by observer and angle class showed two of the observers (D and I) increasing over estimation of their magnitude of error with increase in angle size, and two observers tending to underestimate angle size as absolute angle increased (Fig. 4).

DISCUSSION

Accurate line transect surveys are essential if Marbled Murrelet at-sea monitoring programs are to have the statistical power to detect changes in population density. Errors in estimating the distance of murrelets from the transect line may increase the variation in density estimates and erode power to detect trends (Buckland et al. 1993, Becker et al. 1997). If distances and angles were consistently overestimated, lower estimated densities would be calculated. Conversely, if distances and angles were underestimated, densities would be overestimated. If there were no consistent bias among all surveys, but a bias within particular surveys, this would increase the variance among survey density estimates, eroding power to detect trends over time.

Our preliminary results show that well trained observers can make accurate estimates of angles and distances, which are necessary to calculate the density of birds using line transects. The 727 distance estimations and 209 angle estimations show low magnitudes of error of -2.2 m and 2.1° respectively, for the pooled data. There was some variation, however, that could be explained by observer variation for estimates and actual angle size for angle estimates.

NEXT STEP

This preliminary data will be used to model the effect of these calculated errors on density estimates. We will perform Monte Carlo simulations of distance and angle errors along an actual transect. This will produce replicates of the transect with the effects of distance and angle errors explicitly shown in the model as new values. The results will then be analyzed with Distance line transect software to model the impact of these errors on actual density estimates. Finally, a calculation of the effect of observer error on power to detect trends will be performed. This analysis will quantify the impact of measurement errors on attempts to monitor Marbled Murrelet populations.

The degree of training that is needed to ensure accurate estimators could be studied by testing novice observers before training and subsequent testing. This could reveal the amount of training necessary before surveys are performed. Training and testing should be done prior to surveying until observers are highly accurate. The learning curve may be quite high, or only require several sessions of initial training and testing before surveying can commence.

This study, in combination with research testing the two other line transect sampling assumptions will help to insure that the line transect method is appropriate for surveying Marbled Murrelets at sea.

LITERATURE CITED

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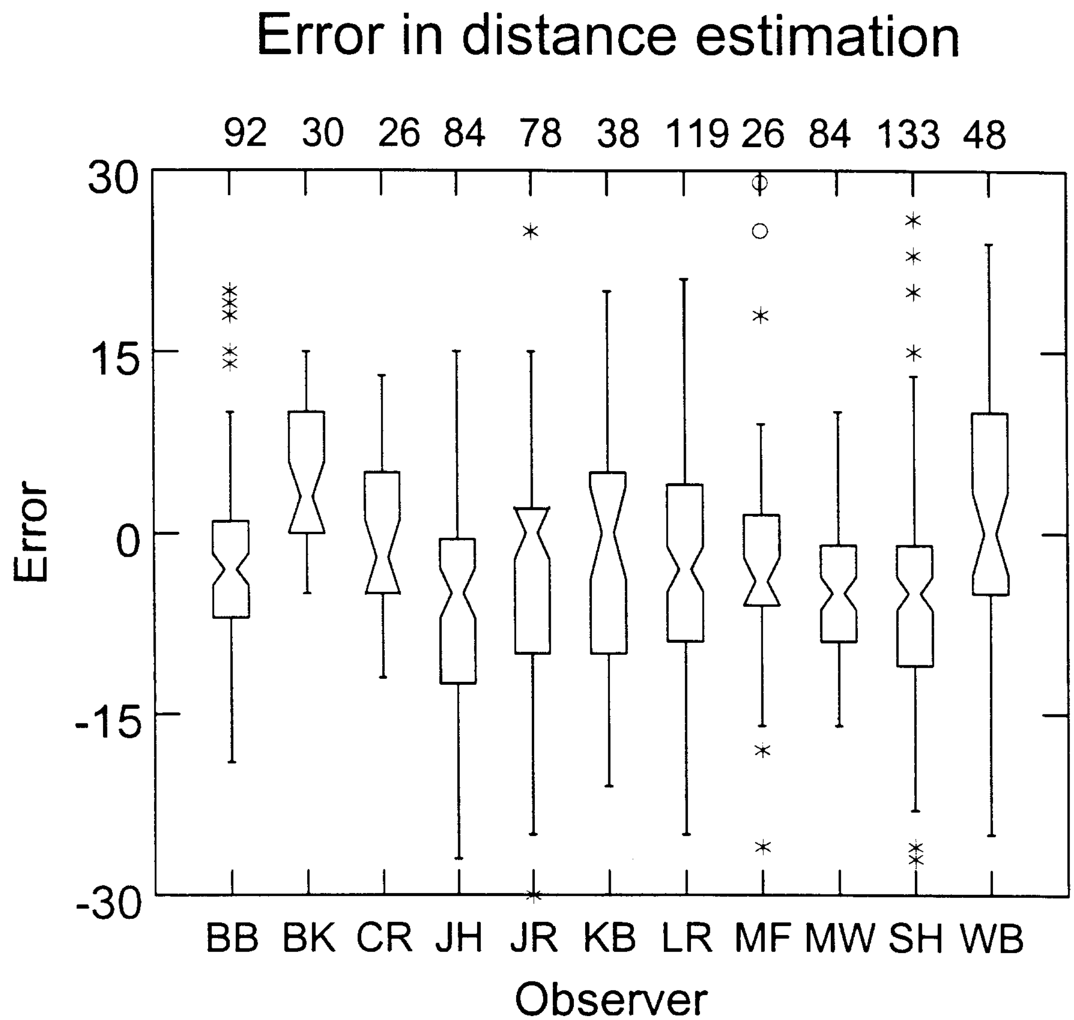

Figure 1. Error in distance estimation for 11 observers in 1997 and 1998 (n = 727). Pooled mean error for all observers is -2.2 ± 3.2 m..

RESULTS OF TWO-WAY ANOVA

Source	Sum-of squares	df	Mean-Square	F-ratio	P<
Distance	229	2	114	1.535	0.216
Observer	4773	10	477	6.391	0.001
Interaction	3079	20	154	2.062	0.004
Error	51834	694	75		

Table 1. Two-way ANOVA of the effect of distance class (0-40, 40-80, and 80-120 m) and observer on distance estimation error (n = 727).

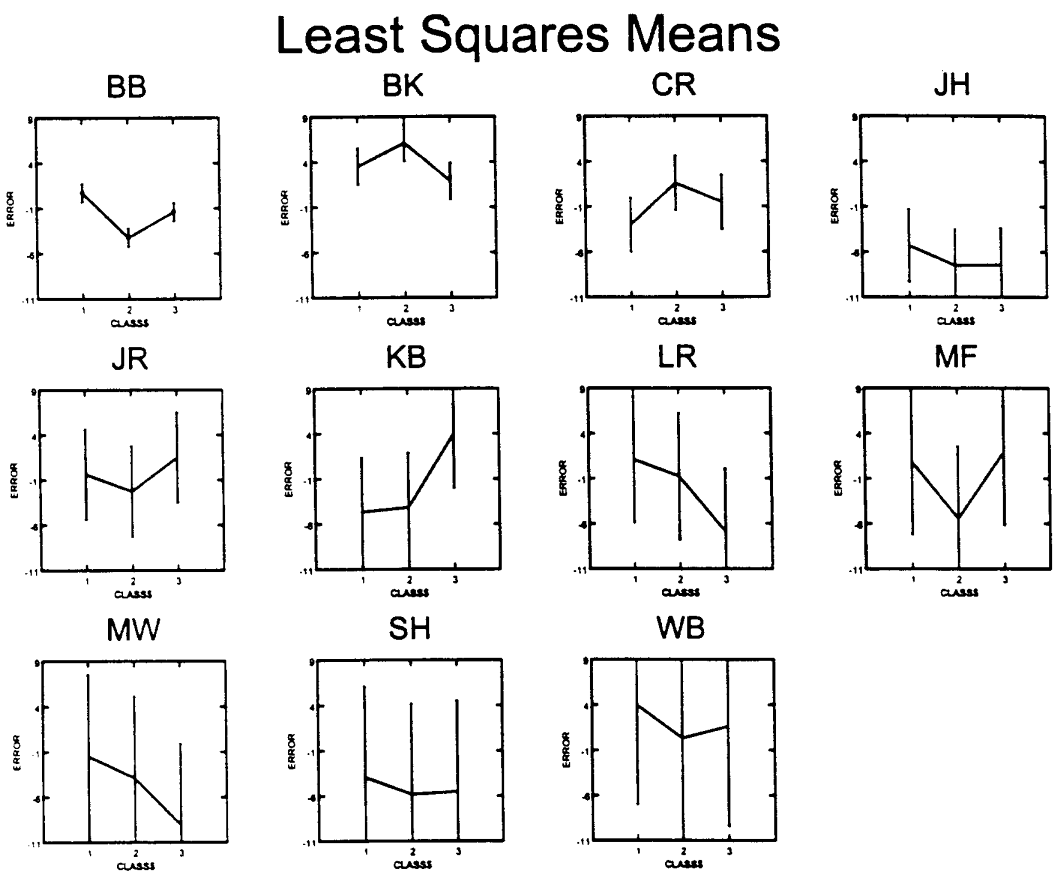

Figure 2. Least squares means of distance error by observer and distance class (0-40, 40-80, and 80-120 m). The graph headings are observers. Class 1 represents 0-40 m, class 2 represents 40-80 m, and class three represents 80-120 m).

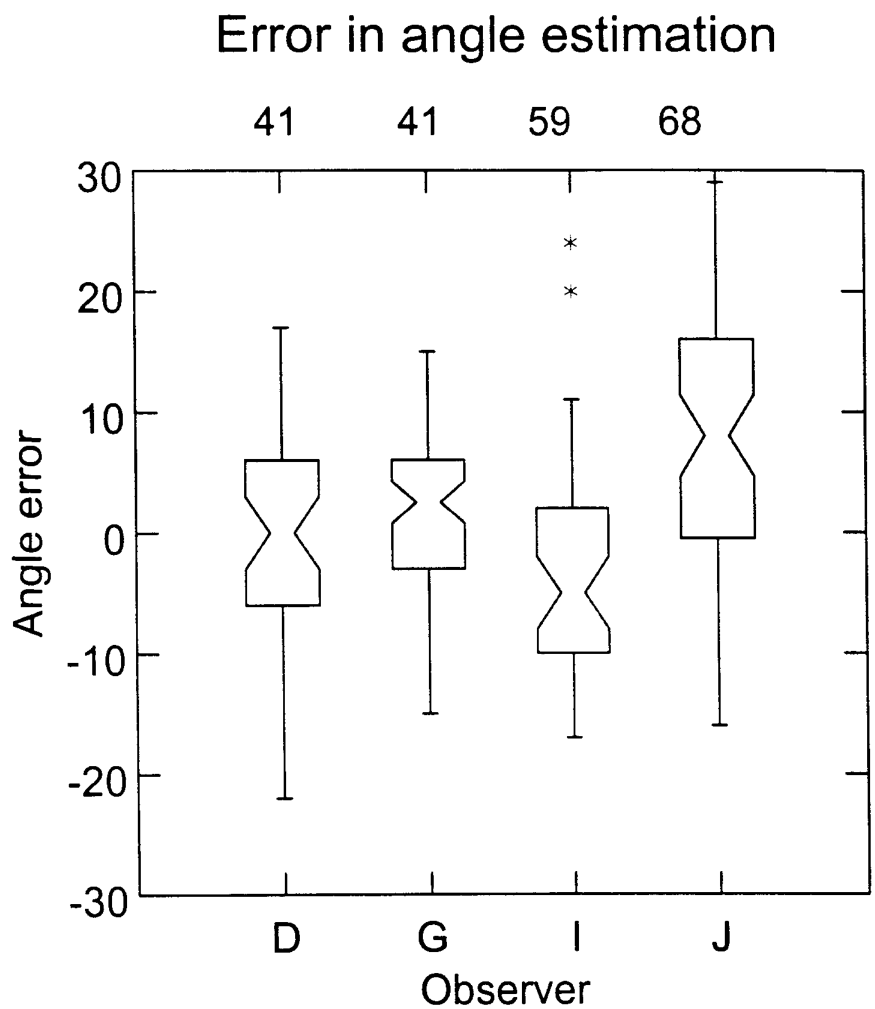

Figure 3. Error in angle estimation for four observers in 1997 and 1998 (n = 209). Pooled mean error for all observers is 2.1 ± 10.4°.

RESULTS OF TWO-WAY ANOVA

Source	Sum-of-squares	df	Mean-Square	F-ratio	P<
Angle	86	3	43	0.473	0.624
Observer	444	2	148	1.623	0.185
Interaction	1917	6	320	3.505	0.003
Error	17964	197	91		

Table 2. Two-way ANOVA of the effect of angle class (0-30°, 30-60°, and 60-90°) and observer on distance estimation error (n = 209).

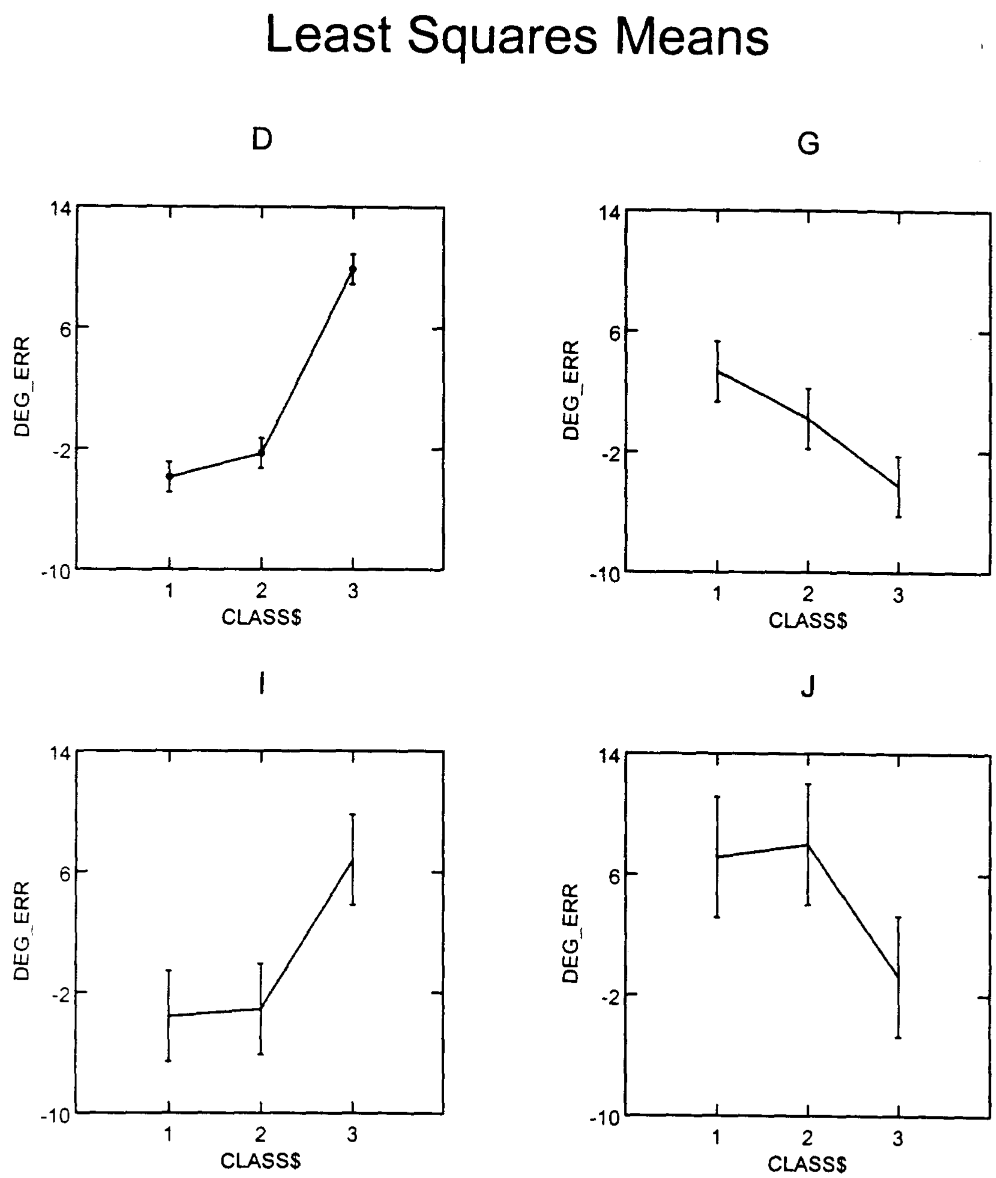

Figure 4. Least squares means of angle error by observer and angle (0-30°, 30-60°, and 60-90°). D, G, I, and J are observers. Class 1 represents 0-30°, class 2 represents 30-60°, and class three represents 60-90°).